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SYNTHESIS OF CERAMIC COMPOSITE MATERIAL BY POWDER METALLURGY METHOD AND OPTIMIZE PROCESS PARAMETERS IN REGRESSION METHOD IN MACHINING MICRO ABRASIVE AIR JET EROSION TESTER

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ABSTRACT

Aluminium reinforced zirconium composite materials provide excellent structural fabrics that combine high wear resistance, electrical resistance and additional toughness results. In this sample, composites containing different concentrations of zirconium applied to aluminium oxide are 5 per cent wt., 10 per cent wt. and 15 per cent wt. using a powder metallurgy milling process. Test preparation and examination of the sample wear intensity and surface roughness by the Taguchi process. Ultra-n- ZrO2 Ceramic powder particles are uniform distribution in ultra-n- Al2o3 particles with a mild agglomeration. The incorporation of Ultra -n- zirconium dioxide particles into aluminium leads to aluminium composites with increased mechanical and electrical properties. Aluminium reinforced zirconium Ceramic composites are a good surface finish. This research paper introduced a new technique for investigation of process parameters of AL2O3 reinforced zirconium ceramic composites on MAAJM. The analysis of the process parameters was carried out by the Taguchi Method. Experiments have been conducted on ceramic composite specimens, the control parameters of machining such as P, AFR, SOD and material type. 30µm size of Silicon Carbide (sic) sand Particles are impregnated with AL2O3 Ceramic composite materials are controlled by the reaction considerations in particular Erosion rate and surface roughness. The optimal degree of the criteria examined using the Taguchi process has a direct impact on the surface quality, dimensional accuracy and useful life of the materials.

***KEYWORDS:** Ultra- n Al2o3, Ultra n Zro2, Sintering, Sic Particles, DOE, ANOVA & MAAJM*

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Original Article

INTRODUCTION

Ceramics in general can be characterized as the art and science of producing and using solid objects composed of inorganic and non-metallic materials for practical applications. Usually, ceramics are manufactured by synthesized powders, accompanied by moulding and consolidation processes that make it easy to create items in different shapes and sizes. In recent years, we have learned that ceramics and composites can also be used to strengthen or remove different parts of the body, especially bones. The most ubiquitous form of alumina is the alpha-form al_2o_3, which has a rhombohedra structure. Reinforcement of zirconium was to improve mechanical properties [6] Pure zirconium is monoclinic at room temperature and tetragonal (t) and then shifts the shape to cubic (c) when the sintering temperature increases. It is noteworthy that the tetragonal to monoclinic phase transition during [7]. Nano reinforced aluminum Nano composites are produced using zirconium dioxide (n-ZrO2). The prepared specimens are evaluated according to their hardness. The above

mentioned properties were chosen because of the added reinforcement (n-ZrO2) which is known to have good durability and durability, among other structural properties at room temperature. The incorporation of n-ZrO2 particles into the aluminum matrix can lead to the production of aluminum composites with improved hardness and wear resistance. These composites can be used in automotive components [8]. Zirconium has been commonly used as reinforcement for many ceramics due to its high strength and resistance to fractures [9]. The relative density of flexural strength, Vickers Micro hardness and fracture strength increased with an increase in sintering temperature [10][11]. The effect of adding nano ZrO_2 and Al_2O_3 on mechanical properties developed by hot pressing which possesses high physical and mechanical properties. [12] Yet its poor hardness has always been a major issue than other competitive ceramics. The combination of strong ceramic materials such as Al_2O_3 with a high strength ZrO2 matrix is therefore a good way to produce an outstanding composite reinforcement and enhance the mechanical properties of the frame. Manufacturing tough and good physical, mechanical and electrical ceramic composite materials is difficult to produce due to their inherent fragility. The precision and surface consistency of the work piece is more critical in any manufacturing sector. And make aluminium reinforced zirconium ceramic composite materials use powder metallurgy techniques. This investigation includes 5%wt, 10%wt and 15% wt zirconium dioxide added to aluminium dioxide respectively. Mixed powder utensil compacted by means of a hydroelectric press in a square shaped die under a constant load of 15kN obtained Green compact of 50mm*50mm*5 mm thickness of the specimen after pressing. Green compact specimen sintered in a box oven maintained at a constant temperature of 1500^0C of 330min. and cooled in a furnace at 300 min. after sintering the specimen is polished, a pure al_2o_3 specimen is prepared in this way, adding 5wt. percent, 10wt. percent, 15wt. percent, Zirconium and pure Zro_2 specimens. Unconventional machines could be used during this method to remove unwanted material removed by energy from the surface of the specimen. In any manufacturing industry, the precision and surface quality of the work piece is most important. In this research, alumina strengthens zirconium ceramic composite material is very hard and fragile material so micro abrasive machining is the best technique for manufacturing quality surface work pieces. AJM is a slower process, expanding the air makes it much cooler and lower forces and much cheaper process. Replacement of the tool in USM is a long process, the new tool has to be brazed on the shaft; in AJM, and the nozzle is simply screwed on. Additionally, the same machining parameters cannot be used for comparative purposes for both methods[1]. This is a high-efficiency and low-cost machining method for fragile materials such as glasses, silicones and ceramics with significant applications in semiconductors, electronic devices, MEMS, flat panels and micro-fluidic devices[2] Abrasive might be awful micro non-metallic hard particles, Abrasive air-mixed particles have been impregnated with different cutting pressures[3] The carrier gas pressure ranges between 2 and 10 bar, and abrasive particles such as Silicon Carbide, Aluminium Oxide and glass beads are introduced in sizes from 10 µm to 50 µm[4] For ductile and brittle material, the removal process for solid particle degradation is not the same. The ductile material is subject to weight loss due to the plastic deformation phase [5].

SYNTHESIS Al_2O_3 REINFORCED Zro_2 CERAMIC COMPOSITE MATERIAL

Particles size 300 nm of alumina commercially available and particle size 400 nm of zirconium powder.

Figure 1: Alumina Powder.

Figure 2: Zirconium Powder.

Vibratory Milling Method: This mill contains an electric motor connected to the drum's shaft by an elastic coupling drum that is usually lined with wear resistance material so that it consists only of ceramic material. During operation 80 per cent of the container filled with starting Powders here, the vibratory motion is produced by an eccentric shaft mounted inside the mill on a plate. Eccentric movement of the shaft allows the Drum of the vibrating machine to work.

Compacting: Mixed powder ware compacted in die; machined Die is made of cemented carbide material. Powders are compacted in a die by means of a hydraulic press with a steady load of 15 kN.

Figure 3: Vibratory Mill

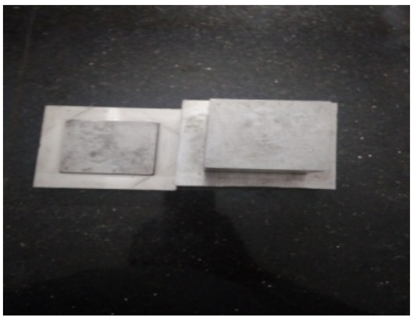


Figure 4: Cemented Carbide Die

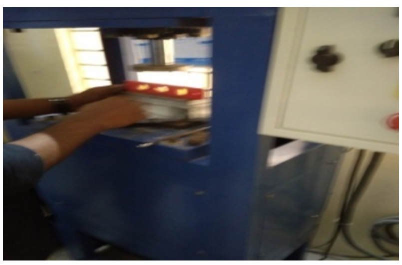


Figure 5: Hydraulic Press

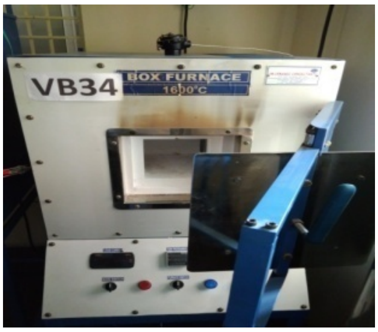


Figure 6: Box Furnace (1600^{0}C)

Sintering: Green compact composite material is held for 330 minutes in box furnace and sintered at 1500^{0}C and cooled in furnace at 300 minutes sintering procedure performed with ceramic composite material at 70 percent melting point. Mechanically bound powder particles are sintered during the sintering process to increase Mechanical and electrical properties of the ceramic plates.

EXPERIMENTATION AND METHODOLOGY

Plan of Experiment

In any manufacturing industry, cost is more important than quality, but quality is the best way to reduce cost. Taguchi is a statistical method developed by Genichi Taguchi. This method determines the optimum results for control factors. Experiments results are used to analyze the date and predict it and find out optimum level of control factors and reduce the variability. Design of Experiments OA Indicates combination of input parameters Signal to Noise ratio is higher and it will be considered as an excellent parameter. This is to determine relation between process parameters and responses and to optimize the responses. This method is to reduce the input to output ratio. In this research, consider four variables and three levels as shown in Table1. The experiment plan consists of 27 tests wherever the second, third, fourth and fifth columns are assigned to the P in bar, AFR in gm/min, SOD in mm and Material type in percentage of zirconium composition and responses are erosion rate and roughness on surface.

Figure 7: AAJ erosion Tester.

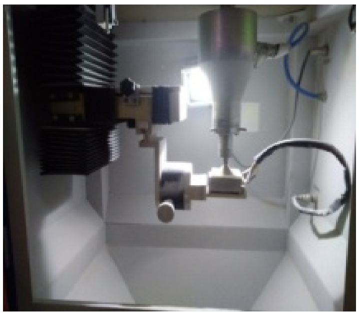


Figure 8: During Operation.

Material

Figure 9: Before Machining.

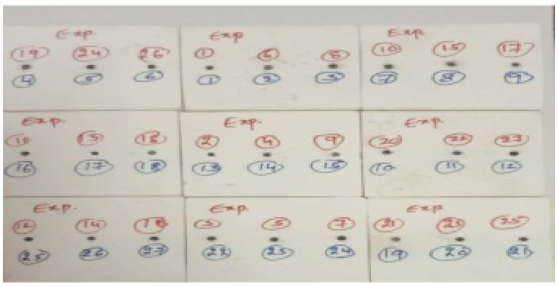


Figure 10: After Machining.

Al_2O_3 Reinforced ZrO_2 Ceramic composite materials are 50x50x5 mm thick specimens are shown in this study as figure 9 (Before Machining) and figure 10 (After Machining).

Measurement

Surface Erosion Rate

To determine the Erosion rate by using the weight method, first measurement of the weight of the alumina reinforcement of the zirconium composite plates prior to machining and the abrasive air jet machining was carried out on specimens with a given time period after that measurement of the final weight of the composite plates using a digital weighing machine.

Erosion Rate = Difference of the Weight of the composites before and after machining to the machining time in sec.

Surface Roughness Measurements

Surface measurement is one of the highest quality control outputs to ensure that the functional surface of the manufacturing

parts is confirmed in accordance with specified standards. In this research to measure the surface roughness by using contact type surface roughness tester.

Table 1: Control Process Parameters

Process Parameters	Units	Notation	Levels		
			1	2	3
Pressure	bar	P	2	4	6
Abrasive flow rate	gm/min	AFR	4	6	8
Standoff Distance	mm	SOD	5	10	15
Material	….	M	5%	10%	15%

Table 2: Results and their S/N Ratios on Erosion Rate

Exp No.	Pressure (bar)	AFR (g/min)	SOD (mm)	Material	SER mg/min	S/N (db)
1	2	4	5	5	0.365	-8.754
2	2	4	10	10	0.485	-6.285
3	2	4	15	15	0.245	-2.216
4	2	6	5	10	0.596	-4.495
5	2	6	10	15	0.557	-5.082
6	2	6	15	5	0.348	-9.168
7	2	8	5	15	0.463	-6.688
8	2	8	10	5	0.456	-6.820
9	2	8	15	10	0.245	-2.216
10	4	4	5	5	0.425	-7.432
11	4	4	10	10	0.546	-5.256
12	4	4	15	15	0.546	-5.256
13	4	6	5	10	0.632	-3.985
14	4	6	10	15	0.532	-5.481
15	4	6	15	5	0.362	-8.825
16	4	8	5	15	0.643	-3.835
17	4	8	10	5	0.486	-6.267
18	4	8	15	10	0.489	-6.213
19	6	4	5	5	0.636	-3.930
20	6	4	10	10	0.716	-2.901
21	6	4	15	15	0.551	-5.177
22	6	6	5	10	0.714	-2.926
23	6	6	10	15	0.936	-0.574
24	6	6	15	5	0.725	-2.793
25	6	8	5	15	0.876	-1.149
26	6	8	10	5	0.868	-1.229
27	6	8	15	10	0.664	-3.556

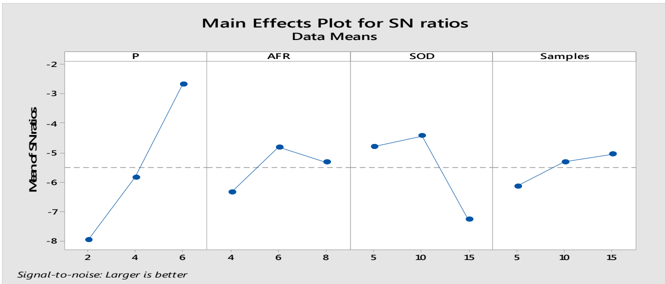
Analyzed control factors are shown in Table1. (Pressure, Abrasive flow rate, Standoff distance and Material Type) The experimental design, tests for Erosion rate and surface roughness and input to output ratios are shown in Tables 2 and 6. The S / N ratio is shown at each control factor point and how it changed when the parameters for each control factor were adjusted from level 1 to level 3. The influence of interactions between control factors has been neglected. The control factor impact was determined by the value of the differences. The higher the difference, the more powerful the factors were.

Table 3: Signal To Noise Ratio For The Erosion Rate

Level	P (Bar)	AFR (G/Min)	SOD (Mm)	Samples (%)
1	-7.970	-6.357	-4.800	-6.136

2	-5.839	-4.815	-4.433	-5.315
3	-2.693	-5.331	-7.269	-5.051
Delta	5.277	1.542	2.836	1.084
Rank	1	3	2	4

It could be seen that Table3 shows that pressure imparted the strongest impact, accompanied by standoff distance, Abrasive flow rate and, lastly the material type. The difference between the third level and first level was about 5.277 db. The second significant parameter was standoff distance. The discrepancy between the second level and the third level was observed to be roughly 2.836 db, third significant parameter was abrasive flow rate, The discrepancy between the second level and the second level and the first level was found to be about 1.542 db, the last significant parameter was material type. The discrepancy between the third level and the first level was found to be about 1.084db



Graph 1: Main Effects Plot for The S / N Ratios

Graph 1 shows the main effects of plots for the erosion rate of the work piece for S / N ratios, respectively. The larger is the S/N Ratio, the smaller is the variance of the erosion Rate around the desired value. Optimal testing conditions of those control factors could be very easily determined from the response graph. The best erosion rate highest S/N Value in the response graph. For the main control factors, graph1 indicates the optimum condition for the tested samples (P_3, AFR_2, SOD_2 and $Sample_3$). Thus, it could be concluded that the best ER of work piece can be achieved and their setting of control factors for tested samples are shown in table 3. Control factors might be very easily determined from the response graph. The best ER value was at the higher S/N value in the response graph. For main control factors, graph indicates the optimum condition for the tested samples (P_3, AFR_2, SOD_2 and $Sample_3$) .

Table 4: Optimum Factors on Erosion Rate

Parameter	Level	Value
P	3	6
AFR	2	6
SOD	2	10
M	3	15% Zro_2

From the effects of the input parameters, higher erosion rate was determined under the machining conditions are Pressure (P)=6bar, Abrasive flow rate (AFR)=6g / min, Standoff distance (SOD)=10 mm and the sample is 85 per cent al2o3 + 15 per cent ceramic composite material when machined by abrasive air jet machine. Experimental work was carried out on various $Zr0_2$ reinforcements in aluminum oxide using the optimal control factors found. The erosion rate was found to be approximately 0.92mg / min. This value was then converted to the ratio of Signal to noise was about 0.490db. An OA, Signal to Noise ratio and Analysis Of Variance are used in the current study of machining aluminum reinforced zirconium ceramic composites to determine the effective parameters of machining. It was concluded that the pressure was the most impact on the erosion Rate of the control parameters.

Table 5: ANOVA of Erosion Rate Results

Source	Deg	Sum of Square	Mean Square	F-Value	P-Value	% of Contribution
P	2	0.499	0.249	37.85	0.000	61.0
AFR	2	0.047	0.023	3.62	0.048	5.83
SOD	2	0.126	0.063	9.59	0.001	15.4
Material	2	0.025	0.012	1.97	0.168	3.17
Error	18	0.118	0.006	….	…	14.5
Total	**26**	**0.811**	**…**	**….**	**…**	**….**

R^2=0.9549, R^2 (Adj.) = 0.8904

Regression Equation for Surface Erosion Rate at 99% Confidence Level

SER^0.1=0.5595-0.1417P2-0.0416P4+0.1834P6-0.0579AFR4+0.0407AFR6+0.0171AFR8+0.0349SOD5+0.0607SOD10-0.0956SOD15-0.0405Sample5%+ 0.0057Sample10%+0.0057 Sample15 % (I)

An Analysis of Variance was used to determine the percentage contribution of the each control parameter of the erosion Rate on the Micro abrasive air jet machining of aluminum reinforced zirconium ceramic composites. The results shown in table 5 of the ANOVA illustrates erosion rate in the processing of ceramic composites. Apart from the DF, SS, MS and F-Calculations and P values was presented. This analysis was carried out at a confidence level of 99 percent and the F value of each design parameter was calculated. Calculated value of F showed control parameter influence. Highest parameter of influence on erosion rate was Pressure (P) hence F- calculation was equal to 37.85, so the control parameter (P) is the most significant parameter, but the control parameters for the StandOff Distance (SOD), the Abrasive Flow Rate (AFR) for the material removal rate since F calculations were equal to 9.59, 3.62 and 1.97. Abrasive flow rate, standoff distance and material type also had significant on erosion rate. The last column in the table showed each control factor's percentage contribution. Thus, the degree of influence exhibited on the result. It was important to observe the percentage contribution values of each factor shown in Table 3. The Pressure (P) parameter is the highest contribution to the Material Removal Rate (P≈61.02%), followed by the Standoff distance (SOD≈15.46%), the Abrasive Flow Rate (AFR≈5.83%) and finally the Material Type (M≈3.17%).

Surface Roughness (Ra)

Table 6: Results and Their S/N Ratio on Ra

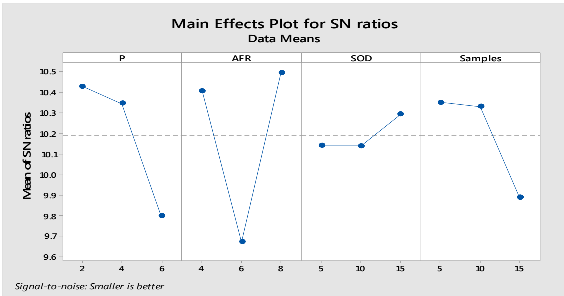
Exp. No.	P(bar)	AFR (g/min)	SOD (mm)	Material	Ra (µm)	S/N Ratio (db)
1	2	4	5	5	0.32	9.897
2	2	4	10	10	0.31	10.172
3	2	4	15	15	0.30	10.457
4	2	6	5	10	0.31	10.172
5	2	6	10	15	0.33	9.629
6	2	6	15	5	0.34	9.370
7	2	8	5	15	0.29	10.752
8	2	8	10	5	0.27	11.372
9	2	8	15	10	0.25	12.041
10	4	4	5	5	0.27	11.372
11	4	4	10	10	0.29	10.752
12	4	4	15	15	0.31	10.172
13	4	6	5	10	0.33	9.629
14	4	6	10	15	0.33	9.629
15	4	6	15	5	0.30	10.457
16	4	8	5	15	0.29	10.752

17	4	8	10	5	0.31	10.172
18	4	8	15	10	0.31	10.172
19	6	4	5	5	0.30	10.457
20	6	4	10	10	0.29	10.752
21	6	4	15	15	0.33	9.629
22	6	6	5	10	0.35	9.118
23	6	6	10	15	0.36	8.873
24	6	6	15	5	0.31	10.172
25	6	8	5	15	0.35	9.118
26	6	8	10	5	0.32	9.897
27	6	8	15	10	0.31	10.172

Table 7: S/N Response Table for Surface Roughness (Ra)

Level	P (bar)	AFR (g/min)	SOD (mm)	Material
1	10.430	10.407	10.141	10.352
2	10.346	9.673	10.139	10.332
3	9.799	10.495	10.294	9.891
Delta	0.630	0.822	0.155	0.462
Rank	2	1	4	3

It could be seen from Table 7, greatest impact parameter was the Abrasive Flow Rate as it was accompanied by Pressure, Material Type and lastly Standoff distance. The third level of the abrasive flow rate was about 10.495db while the first level was about 10.407db; the difference was the largest of 0.822db. Despite pressure, the difference between the first and second levels was observed to be about 0.630db, again a significant level. It is accompanied by the material type, the difference between the first level and the second level was observed to be about 0.462db, which indicates again a significant level, the standoff distance is shown to have the least effect on the roughness of the surface since the disparity between the third level and the first level was about 0.155 db, which is again a significant level.



Graph 2: Main Effect Plots for S/N Ratios.

Graph 2 Shows the main impact plots for the aluminum reinforced zirconium composite experiment with S / N ratios for surface roughness. The greater the ratio of S / N is the smaller the disparity in surface roughness around the target value. For these control variables, the response graph could very easily determine optimum test conditions. In the answer graph, the best highest surface roughness value S / N. Graph2 shows the optimum condition for the samples tested for the main control factors (P_3, AFR_2, SOD_3, and $Sample_1$). It could be inferred that the composite specimen's optimal surface roughness can be obtained, and that their setting of control factors for the checked samples is shown in table 7. Control variables could be very easily determined from the response table. In response graph, the best surface roughness value was for the higher S / N value. Graph2 shows the optimal condition for the samples tested (P_3, AFR_2, SOD_3 and $Sample_1$) for the main control factors.

Table 8: Optimum Factors of Surface Roughness

Parameter	Level	Value
P	3	6
AFR	2	6
SOD	3	15
M	1	5% Zro_2

From the results of the control factors higher surface finish was obtained under the machining conditions Pressure (P) = 6bar, Abrasive flow rate (AFR) = 6g / min, Standoff distance (SOD) = 15 mm and material is al2o3 + 5 percent Ceramic composite material when machined with micro abrasive air jet machine at 99 percent confidence level. Experimental work was carried out on the different zro2 reinforcement of aluminium oxide using the optimal control factors identified. The surface roughness was estimated to be approximately 0.27 µm. That value was then transferred to the S / N ratio (db), the average S / N ratio was calculated and was approximately 8.927 db. In the current study on the machining of zirconium reinforced aluminium ceramic composites, Effective machining parameters such as pressure abrasive flow rate, standoff distance and material type were calculated using orthogonal design, S / N ratio, and ANOVA. It was concluded that the abrasive flow rate was found to be the most significant on surface roughness.

Table 9: ANOVA for Surface Roughness

Source	DF	(SS)	(MS)	F-Calc.	P-Value	% Contri.
P	2	0.00440	0.00134	3.03	0.073	25.76
AFR	2	0.00807	0.00232	5.23	0.016	47.21
SOD	2	0.00018	0.00009	0.21	0.814	1.08
Samp.	2	0.00156	0.00078	1.76	0.201	9.14
Error	18	0.00800	0.00044	--	--	
Total	**26**	**0.01709**		**--**	**--**	

R^2=0.9321, R^2(Adj.) = 0.8741

Regression equation for Surface Roughness

Ra^0.1=0.31037-0.00815P2-0.00593P4+0.001407P6-0.00815AFR4+0.01852AFR6-0.01037AFR8+ 0.00185SOD5+0.00185SOD10-0.00370SOD15-0.00593Sample5% of Zro2-0.00481 Sample10% of Zro2+0.01074 Sample15% of Zro2

An Analysis of Variance was used to determine the percentage contribution of the each control parameter of the surface roughness. Aluminium reinforced zirconium ceramic composites on the Micro abrasive air jet machining. Its details are shown in table 9. In addition to the Degree of Freedom (DF), the sum of squares (SS), the mean squares (MS), the F-Calculations and the P values have been shown. In this research work to analyze the process parameters at a confidence level of 99 percent and the F value was calculated for each parameter. F calculated value showed control parameter impact. The highest influencing parameter on the surface roughness was the abrasive flow rate (AFR), hence F-Calculation of the abrasive flow rate was equal to 5.23, followed by the pressure (P), material (M) and finally Standoff distance (SOD), since F calculations were equal to 3.03,1.76 and 0.21 respectively. Abrasive flow rate, standoff distance and material type also had significant on the surface roughness. The last column of the table shows the percentage share of each control element. It indicates the degree of influence of the result. It was necessary to note the percentage contribution values for each factor shown in Table 3. The parameter Abrasive Flow Rate (AFR) is the highest contribution to surface roughness (AFR≈47.21 percent), followed by pressure (P≈25.76 percent), material type (M≈9.14 percent), and finally

Standoff distance (SOD≈1.08 percent).

CONCLUSIONS

- Make composite materials use powder metallurgy techniques. In this approach, the use of system processing methods can be avoided or significantly reduced by drastically reducing performance errors and often resulting in lower cost overheads. It is also used to make it impossible for different products to melt or mould in other ways.
- The OA was used to analyze the input parameters impact on the erosion rate. The results showed that the main impact parameter was the air pressure accompanied by standoff distance, Abrasive Flow Rate and eventually the material type.
- The approximate S / N ratio using the optimum erosion rate tested parameters has been determined and the highest significant parameter showing pressure.
- ANOVA indicated that Parameter Pressure was the highest percentage contribution accompanied by SOD, AFR and finally type of specimen at 99 per cent confidence level.
- The % contribution of input parameters such as pressure, stand-off distance, abrasive flow rate and material type was approximately 61 percent, 15.4 percent, 5.83 percent and 3.17 percent respectively on the rate of erosion.
- The approximate S / N ratio using the optimum surface roughness tested parameters has been determined and the abrasive flow rate parameter is the strongest.
- ANOVA indicated that the abrasive flow rate parameter was the highest percentage contribution followed by air pressure, the material type was finally the standoff distance.
- The percentage contribution of the abrasive flow rate, air pressure, material type and standoff distance was approximately 47.21%, 25.76 %, 9.14% and 1.08%.

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